KARSTRESEARCH
- a traditional science involving recent applied tasks

Homage to Prof. JAKUCS
The famous Hungarian Karst scientist
who introduced applied karst research in his department

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1. PREFACE

During the last 150 years, the research done concerning karst phenomena and central questions changed tremendously.

First, karst research was primarily done at Universities with the main emphasis on basic research. Due to the change in responsibility from Universities to engineering offices, regional planning agencies and federal environmental conservation agencies, it is now becoming more important to apply basic knowledge. As a consequence, problems concerning ecology and environmental conservation are solved by referring on classical basic research. Obviously, this change in responsibility reveals in research and teaching. It is also well displayed in (Master) theses and publications (EK 1985, GAMS et al. 1987, PFEFFER 1990, JULIAN 1992, WILLIAMS 1993).

2. THE SITUATION OF KARST RESEARCH IN ITS BEGINNING

The systematical scientific reconnaissance, specification and explanation of natural phenomena started during the last century. In the middle of the last century, the efforts made eventually became part of several textbooks. These textbooks are considered to be the foundation for present physical geography and, especially, of present geomorphology (NAUMANN 1854, PESCHL 1869, RICHTHOFEN 1886, MAUL 1938, LOUIS & FISCHER 1979). Geographers and geologists spent much attention to the natural phenomenon that is now known as KARST. This was because of its specific landforms within certain lithofacies and its uncommon subterranean drainage combined with cave-systems. In addition, since the antiquity hydrogeological knowledge has been existed (PFEIFFER 1963). In karst regions, hydraulic engineering was used to construct buildings which are supposed to be evidences of early "applied science" (BALLIF 1896, ZÖTL 1974, JAKUCS 1977, NICOD 1972).

Hydraulic engineering was used to control the water economy of karst springs and the seasonal or partly constant inundation of poljes (DENK 1974). As early as the 1st century AD efforts, were made in the Conca di Fucino in Italy (HASSERT 1897), followed by the drainage of the polje of Cuges in the 15th century (BOUZAT 1969). As a matter of fact, the long experience over centuries in hydraulic engineering and the technical facilities of the industrial age enabled the quite successful drainage of the Lake of Fucino from 1854-1875 (HASSERT 1897), of the Kopai depression in Greece from 1883 until 1892 (PHILIPSON 1894) and of the dalmatian poljes (BALLIF 1896).

Due to some lack in basic knowledge about karst hydrology, however, man's impact in karst hydrology sometimes was - and still is - rather unsuccessful (BALLIF 1896, NICOD 1972, ZÖTL 1974, JAKUCS 1977, GAMS et al. 1987). Despite of the recent profound knowledge in karst hydrology (DREYBRODT 1988, FORD & WILLIAMS 1989), spectacular ruins are still the result in some cases of application (ZÖTL 1974, JAKUCS 1977, GAMS et al. 1987).

3. Basics and vocabulary of the self-establishing science

As always when a new science is established, the first step was to create a technical terminology defining typical features and phenomena. The publications of CVIJIC (1895, 1918) and GRUND (1914) along with the textbook of Albrecht PENCK (1904) are probably the most important acts referring to karst morphology. However, opposite views about karst hydrology, processes and dynamics of subterranean drainage and cave genesis were subject of a debate carried on with scientific keenness (PFEIFFER 1963, ZÖTL 1974, BÖGLI 1978). This debate had its first conclusion with the publication of "Hydrographie des Karstes" (O. LEHMANN 1932).

The weakness of this first period is obvious and still is acting as an impediment to the correct use of the nomenclature. This is because karst features were named only by the karst regions being located in the margins of Vienna University. Especially the slovenian region "Kras" was serving as the model landscape that, among other things, provided the term "karst."

Yet little was known about other karst landscapes differing from the model landscape. At the beginning of this century, certain travel notes informed about differing karst regions, eg like in Java or Jamaica (DANES 1908, 1910). Information which was taken from these notes was included in the schools of this time. This was sometimes resulting in rather wrong designations like, for example, by GRUND 1914, who called the karst cones "cockpits." Moreover, the transfer of terms originating from the dinaric area to regions showing totally different landforms and a different history, was not really useful for further research.

During this first phase, GRUND (1914), CVIJIC (1924), SAWICKI (1909), SANDERS (1921) tried to explain karst phenomena in a geomorphological way with models derived from the cycle of William Morris DAVIS (1912). Despite of the progress made after the second World War, several publications of this time still referred to these models as valid ideas of karst genesis (CORBEL 1959, STRAHLER 1969, SMALL 1972). During this first period, studies on hydrological karst processes (KATZER 1909, O. LEHMANN 1932) were carried out without the help of modern tracer and automatic measuring techniques, and also without hydraulic 3-dimensional computer-assisted simulation analysis and modelling. Therefore, ideas of this time are quite incomplete in comparison to recent studies (BUHMANN & DREYBRODT 1985, 1985a, DREYBRODT 1988, FORD & WILLIAMS 1989, WHITE 1988).

4. KARST RESEARCH FOCUSED ON CLIMATIC GENETIC PROCESSES

During the 1930's and the second World War, the economical and political circumstances prevented scientific progress. It was not earlier than in the 1950's, that a new era in karst research evolved due to the international cooperation within the scope of the International Geographic Union (IGU). The rise of modern facilities in travelling and the access to aerial photographs and maps of areas formerly difficult to survey, was followed by a multitude of regional publications. With the protectorate of the IGU, Herbert LEHMANN gave the impulse to create an international atlas of karst phenomena (LEHMANN & MORANDINI 1960).

In its original conception, it should represent selected karst landscapes by topographic maps, plates and text pages. Because of the almost boundless availability of topographic maps, aerial photographs and the multitude of regional publications at this time, however, the original conception became antiquated with the appearance of sheet No.3 (GERSTENHAUER 1964). It was not until the 1980's that, with the protectorate of the Union of International Speleology (UIS), the work on this atlas continued having the following outline. Karst regions are represented by maps which were created by many contributors applying their own specific geomorphological and geoecological mapping methods. Each map is illustrated by detailed text portions (PFEFFER 1986a, 1990a).

International publications, meetings and symposiums gave evidence for the thesis that the different appearances of karst landscapes cannot be longer described by means of the DAVIS cycles. This statement also was already made by LEHMANN in 1936. Well-developed cockpit-karst, for example was always described as an old landscape in terms of DAVIS, but proved to be young. Moreover, in some regions cockpit-karst was sometimes developed since the Neogene, if not since the Quaternary. In contrast to this, dolines formerly dated as young as to speak again in DAVIS cycles, now were dated in the mid or older Tertiary (LEHMANN 1956, 1964, 1970, SWEETING 1972, PFEFFER 1986). Later on, the slogan "climatic genetic styles" was invented, and it was in the 1950's that a new period of research began with the observation of the karst regions of the earth in a climatic genetic context. Qualitative and quantitative sampling techniques should prove the evolution of specific styles (FUCHS, GERSTENHAUER & PFEFFER 1987).
The spatial distribution of specific karst regions and morphodynamic studies provided significant examples, like
* fluvio karst of former periglacial regions (WAGNER 1960)
* old karst landscapes showing dolines in the temperate climates (PALMER 1975)
* cockpit karst in the neogene limestones of the humid tropics (BLUME 1968, BALÁZS 1968, SWEETING 1972)

* the lack of karst hydrology in periglacial regions (CORBEL 1954, 1954a, MUIR & FORD 1985, also ZÖTL 1974, JAKUCS 1977).
* the lack of karst hydrology in arid regions showing surface flow in times of heavy rains and valley cutting (PFEFFER 1975, 1976).

In contrast, qualitative and quantitative measurements yielded contradictions and did not confirm the thesis of climatic genetic processes and landforms.

At first, this was due to the weakness of some measurement methods and the incorrect selection of measurement places (CORBEL 1959). The application of reproducible and specifically selected reliable field techniques, however, yielded values ranging within 10 times throughout the world. These variations appeared in the field of carbon dioxide analysis (MIOTKE 1974), in the field of water chemistry (BÖGLI 1978, BAUER 1962), as well as in balances based on geological time marks like Karrentischen (BÖGLI 1961, CLAYTON 1981) and standard tablets (GAMS 1979). At the same time it was observed that in the tropics as well as in the non tropics, about 50 mm carbonate is eroded in 1000 years when the floor is covered with vegetation (PRIESNITZ 1974, SWEETING 1964).

This discrepancy between the spatial distribution of karst landscapes throughout the world, the geomorphological-geological analysis and the quantitative sampling techniques has not been cleared so far (PFEFFER 1989).

As a consequence, different evaluations can be explained because of this discrepancy. The evaluations range from critical statements up to the rejection of recent carbonate erosion measurement values because of the following facts:

* ecosystems are disturbed by human impact (PFEFFER 1990, GAMS et al. 1987, WILLIAMS 1993)
* many karst landscapes would have been already eroded, if the present measurement values of carbonate dissolution were correct. Nevertheless, karst landscapes are represented by old surfaces covered with paleosoils as well as by bornhardts being sculptured in contrast to surrounding rocks (LEHMANN 1956, TROLL 1973).
* studies indicate that weathering in paleoclimates was more intense and different to present weathering processes (VALETON 1983). In addition, it was mentioned in paleoclimates morphodynamic processes were different because of different geoecological conditions (ROHDENBURG 1971).

For this reason, the application of actualism in geomorphology and morphodynamics is quite dubious.

On the other hand, statements maintain that there are indeed big differences in dissolution and erosion processes because of different climatic conditions (SALOMON & MAIRE 1992). But including all geocomponents, however, karst landscapes primarily differ because of differences in structure and lithofacies (NICOD 1982, SWEETING 1979, DAY 1979, ROSSI 1980, MONROE 1976, SALOMON 1987).

After all, hydrologists claimed that it is more a question of water balance than of climatic genetic processes how karst landscapes will develop. This was verified by model calculations being oriented on mass balances of karst landscapes. Finally, Derek FORD (lecture - Hamilton 1993) and Paul WILLIAMS (lecture Singapore 1995) stated that "tropical cockpit karst" will even develop in a non tropic climate when sufficient water supply is guaranteed. This statement still is examined (BUHMANN & DREYBRODT 1985, 1985a, DREYBRODT 1988, FORD & WILLIAMS 1989, WHITE 1988).

Further basic research concerning these discrepancies will provide more profound knowledge about the evolution of karst landscapes.

5. Karst research as a part of research in ecology and environment

Since even humanity is threatened because of global and regional changes in the ecological system, the relation with nature changed. In contrast to the 1960's, where sociological and economical changes had priority, ecology and environmental conservation nowadays became more important for the management of natural resources.

Even karst research was influenced by this change of mind. Despite of their small aquifers, quite many karst landscapes served as water-reservoirs and karst springs often provide water for some parts of remote urban areas. Furthermore, endangered species of fauna and flora can often be found in karst landscapes. Especially in the European Mittelgebirge, natural resources management and environmental conservation compete with traditional but meanwhile industrial farming, as well as with urban population looking for outdoor recreation (PFEFFER 1990).

Competing kinds of land use require well-devised planning. Therefore, science should try to provide the required parameters for application. In terms of karst, these parameters are, for example,

* **in engineering sciences**: studies in the hydraulics of flow dynamics within the karst system, followed by studies in the karstwater level position. Moreover, possible ways of purifying karst water should be examined.

* **in hydrology**: studies in the action of pollutants in aquatic karst systems and studies in the chemical and dynamical flow behaviour of springs resulting from processes on the karst surface, or especially in the Epikarst.

* **in geography**: the quantification and evaluation of geoecological conditions in karst landscapes, including plants and animals.

Because of the fact that this report is written by a geographer, we now will have a closer look on the latter parameters.

6. TECHNIQUES OF KARST LANDSCAPE ECOLOGY

The goal is to generate a geoecological evaluation as a foundation for environmental conservation planning and resources management. First, spatially prevailing zones must be defined with the help of certain criterions, like geomorphological landforms (karst cones, dry valleys, dolines, Karrenfelder), significant types of meadows and woods or the distribution of subsurface layers (loess, moraine, paleosoils). The combination of a couple of parameters sometimes also works.

Figure 1 shows an example for the definition of spatially prevailing zones in an area located in the karst region Hutton Roof/Cumbria in northwestern England. The parameters "subsurface layers" (limestone, loess and moraine coverage), "soils" (pavement without vegetation, rendzina soils, brown soils) and "vegetation" (pavement without vegetation, grass and fern families) served as criterions.

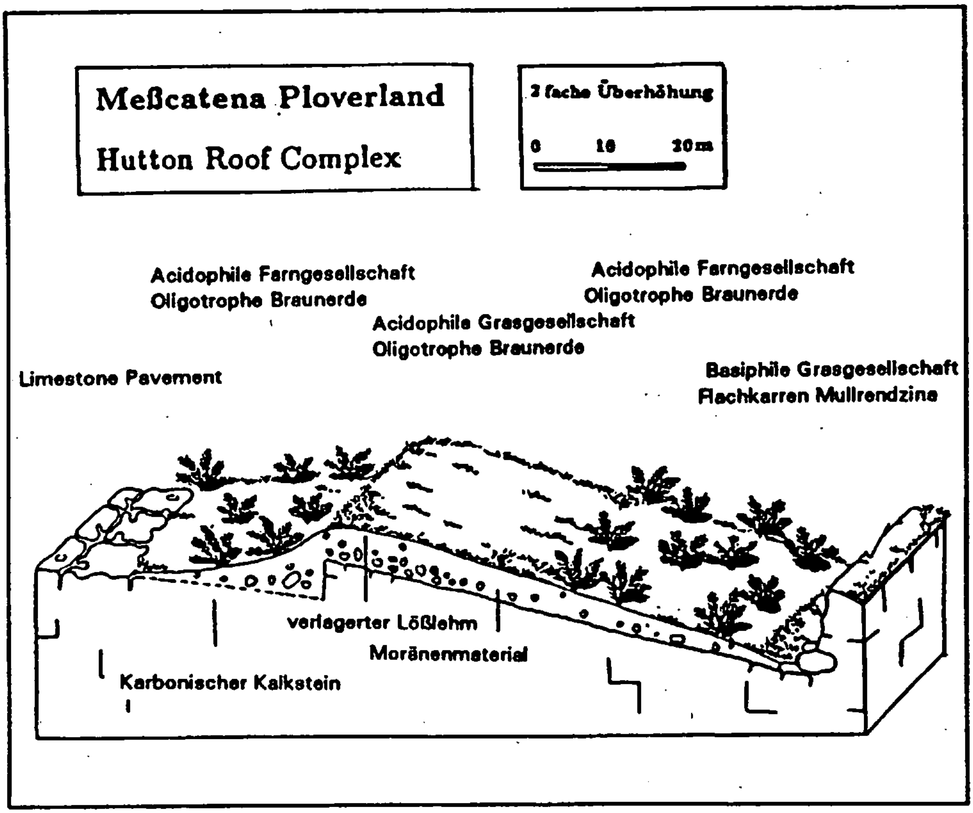


Figure 1 *The definition of spatially prevailing zones (PFEIFFER, P. 1991, Fig. 36, p. 95)*

Within such defined zones sampling places can be selected according to profiles or principles used for catenas or, the simplest way, by a "Typlokalität."

In addition, sampling places are checked by soil samples drilled with the Pürckhauer Bohrstock.

The next step is to map vegetation involving the methods described by BRAUN-BLANQUET (1964) and OBERNDORFER (1990). The identification of the growing conditions of the plants, documented in a system of "Zeigerwerte" (ELLENBERG 1991) enables the following ecological interpretation.

Table 1 shows an example and the result of such a vegetation mapping and the ecological interpretation according to "Zeigerwerten" in a "Kalkmagerrasen Ökotop" located in the Muschelkalk of southern Germany (LEIENDECKER 1992).

The subsequent excavation of a pit provides the possibility to describe the subsurface layer by geological, sedimentological, petrological and soil-scientific techniques.

Figure 2 shows an example of the documentation of a profile located in the "Kuppenalb" area of the southwestern "Schwäbischen Alb" (GOMMEL 1995).

Several layers and pedogenetic horizons serve as criterions for further analysis in a laboratory.

Soil samples are examined with the instructions given by the lab manual (BECK et al. 1994), what means that the soil is analysed by determining its grain size, acidity, exchange of cations, as well as its carbon concentration and nutritive substances. The heavy metal concentration and content of pedogenetic iron or aluminum in solution is analyzed occasionally.

Several textbooks of soil-science (ARBEITSGEMEINSCHAFT BODENKUNDE 1992, KUNTZE, ROESCHMANN & SCHWERDTFEGER 1994, REHFUSS 1990, SCHEFFER & SCHACHTSCHABEL 1989) provide the required limiting values and data for the subsequent ecological interpretation of the data gained in lab analysis. The final interpretation is done by the combination of data gathered by fieldwork and the lab data.

Figure 3 shows an example of the evaluation of a Muschelkalk slope having different vegetation located in a nature reserve in the Main-Tauber Kreis. Furthermore, it shows facts concerning the potential growth of several plants, bushes and erosion.

Objects being under natural protection or objects that eventually will become parts of a natural protection area require a special treatment. This means that mapped vegetation is compared with the Roten Liste (KORNECK & SUKOPP 1988), a list containing all sorts of endangered plants. The system created by MARKS et al. (1989) helps to evaluate how far objects must be protected.

Figure 4 shows an example of the classification of a wet meadow located in the area of the Uracher volcanism of the "Schwäbische Alb" (Ullrich 1992).

Data that has been gathered by the evaluation and analysis of sampling locations is transferred to the previously defined geoecological zones. This is done manually or with a computer using a Digital Elevation Model. A GIS provides the database and the possibility to create hard copies.

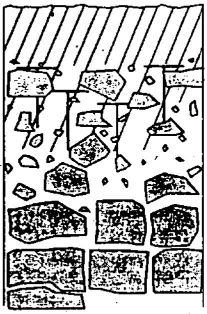
		Zeigerwerte nach ELLENBERG et al. 1991						
Wissenschaftlicher Name	**AM**	**L**	**T**	**K**	**F**	**R**	**N**	**Deutscher Name**
Strauchschicht:								
Juniperus communis	r	8	.	.	4	.	.	Gewöhnlicher Wacholder
Sorbus aria	r	6	5	2	4	7	3	Mehlbeerbaum
Cornus sanguinea	r°	7	5	4	5	7	.	Roter Hartriegel
Krautschicht:								
Anthericum ramosum	3	7	5	4	3	7	3	Ästige Graslilie
Brachypodium pinnatum	1	6	5	5	4	7	4	Fieder-Zwenke
Genista tinctoria	+	8	6	3	6~	6	1	Färber-Ginster
Centaurea scabiosa	+	7	.	3	3	8	4	Skabiosen-Flockenblume
Cirsium acaule	+	9	5	4	3	8	2	Stengellose Kratzdistel
Geranium sanguineum	+	7	6	4	3	8	3	Blut-Storchschnabel
Hieracium piloselloides	+	9	6	4	4~	8	2	Florent. Habichtskraut
Lotus corniculatus	+	7	.	3	4	7	3	Gewöhnlicher Hornklee
Scabiosa columbaria	+	8	5	2	3	8	3	Tauben-Skabiose
Stachys recta	+	7	6	4	3	9	2	Aufrechter Ziest
Teucrium chamaedrys	+	7	6	4	2	8	1	Edel-Gamander
Cornus sanguinea	r	7	5	4	5	7	.	Roter Hartriegel
Aster amellus	r	8	6	6	4	9	3	Kalk-Aster
Bupleurum falcatum	r	6	6	6	3	9	3	Sichelblättr. Hasenohr
Carlina vulgaris	r	7	5	3	4	7	3	Golddistel
Koeleria pyramidata	r	7	6	4	4	7	2	Pyram.-Kammschmiele
Echium vulgare	r	9	6	3	4	8	4	Stolzer Heinrich
Euphorbia cyparissias	r	8	.	4	3	.	3	Zypressen-Wolfsmilch
Gymnadenia conopsea	r	7	.	2	7~	8	3	Mücken-Handwurz
Hypericum perforatum	r	7	6	5	4	6	3	Echtes Johanniskraut
Peucedanum cervaria	r	7	6	4	3	7	3	Hirsch-Haarstrang
Lactuca perennis	r	9	7	4	2	8	2	Blauer Lattich
Linum tenuifolium	r	9	8	4	2	9	2	Zarter Lein
Pulsatilla vulgaris	r	7	6	5	2	7	2	Gewöhnl. Küchenschelle
Sanguisorba minor	r	7	6	5	3	8	2	Kleiner Wiesenknopf
Salvia pratensis	r	8	6	4	3	8	4	Wiesen-Salbei
Gesamtartenzahl	29							
Mittlere Zeigerwerte		7,5	5,8	3,9	3,5	7,7	2,7	
Deckungsgrad Krautschicht (%)	70							
Strauchschicht	<5							
Größe der Aufnahmefläche (m^2)	50							

Table 1 *Vegetation mapping of a "Kalkmagerrasen Ökotop" (LEIENDECKER, T. 1992, Tab.5, p.34)*

sehr stark humose Mull - Braunerde-Rendzina aus geringmächtigen Deckschichten [HL-BL?] über Weißjura-β-Zersatzzone

Lage, Oberflächenrelief: RW-3484,8 HW-5337,3 * 986 m ü. NN * flach geneigter Oberhang in unmittelbarer Nähe zum Albtrauf * 100° e-geneigt

Bodennutzung: Windwurffläche eines Tannen-Wald. in Sukzession begriffen



Ah	0-10 cm	[10YR2/2] * schluffiger Lehm * LD: gering * krü (sub) * karbonatfrei * sehr stark durchwurzelt *
IIBvAh	10-28 cm	[10YR3/4] * schluffiger Lehm * mäßig dicht * sub * karbonatarm * mittel steinig-grusig * stark durchwurzelt *
IIBvCv	28-45 cm	[10YR3/4] * schluffiger Lehm * sub * karbonathaltig * stark steinig-grusig * mittel durchwurzelt *
IIImCv	45-58 cm	[10YR5/4] * schluffiger Lehm * sehr karbonatreich * koh (Kalksplitter in Sandkorngröße sin) * sehr stark steinig-grusig * schwach durchwurzelt *

LEGENDE ZU DEN PROFILBESCHREIBUNGEN

► **Prozesse und Substrate**

- Humushorizont (Ah)
- Lessivierung (Al)
- Tonanreicherung (Bt)
- Verbraunung, Verlehmung (Bv)
- Schrumpfungsrisse
- Konkretionen
- Fe-, Mn-Flecken (beginnende Pseudovergleyung)
- Holzkohlereste
- Pseudomycelien (sekundäre Kalkanreicherung)
- Mergel
- Kalksteine

► **Horizontgrenzen**

scharf — deutlich — diffus

► **Abkürzungen**

Gefügeform

krü	krümelig
sub	subpolyedrisch
pol	polyedrisch
pris	prismatisch
koh	kohärent
sin	singulär

holozäne und pleistozäne Lagen (s. Übersicht)

OL	Oberlage
HoL	Holozäne Lage
HL	Hauptlage
ML	Mittellage
BL	Basislage

Sonstiges

LD	Lagerungsdichte
n.mb.	LD des Feinbodens in sehr steinigem, grusigem Substrat mit Feldmethoden (Eindringwiderstand) nicht meßbar

Figure 2 *The documentation of a profile (GOMMEL, J. 1995, Anhang)*

	Ökotop A	Ökotop B	Ökotop C	Ökotop D
Vegetation	Blaugras-halde	Kalk-Magerrasen	Schwarzkie-fernforst	Schlehen-gebüsch
Hangneigung	39°	32°	33°	33°
C/N-Verhältnis	13	15	10	13
Nährstoffe: - Bedarf[1]	□	□	□	□
- Angebot	□	◩	■	■
- Korrelation	○	○	⚠	⚠
Kupfer-Verfügbarkeit	□	□	□	□
pH-Wert	▼	▽	▽	▽
Verbuschungs-Gefahr	□	□	■	■
Akt. Erosions-Gefährdung	◩	□/◩	□	□
Gründigkeit	□/◩	◩	◩	◩
Bodenfeuchte (mF; ÖF)	□	□	□	□

Erläuterung:

Nährstoffbedarf/Nährstoffangebot/Kupferverfügbarkeit/Verbuschungs-gefahr/Aktuelle Erosionsgefährdung/Gründigkeit/Bodenfeuchte:

□ gering ◩ mittel ■ hoch

Nährstoff-Korrelation (= Verhältnis Bedarf - Angebot):

○ ausgeglichene Verhältnisse ⚠ Überangebot !

pH-Wert: ▽ sehr schwach alkalisch ▼ schwach alkalisch

[1] = Bedarf von Kalk-Magerrasen (ELLENBERG 1986, S. 622f)

Figure 3 *The evaluation of different "Ökotops" (LEIENDECKER, T. 1991, Tab.7, p.59)*

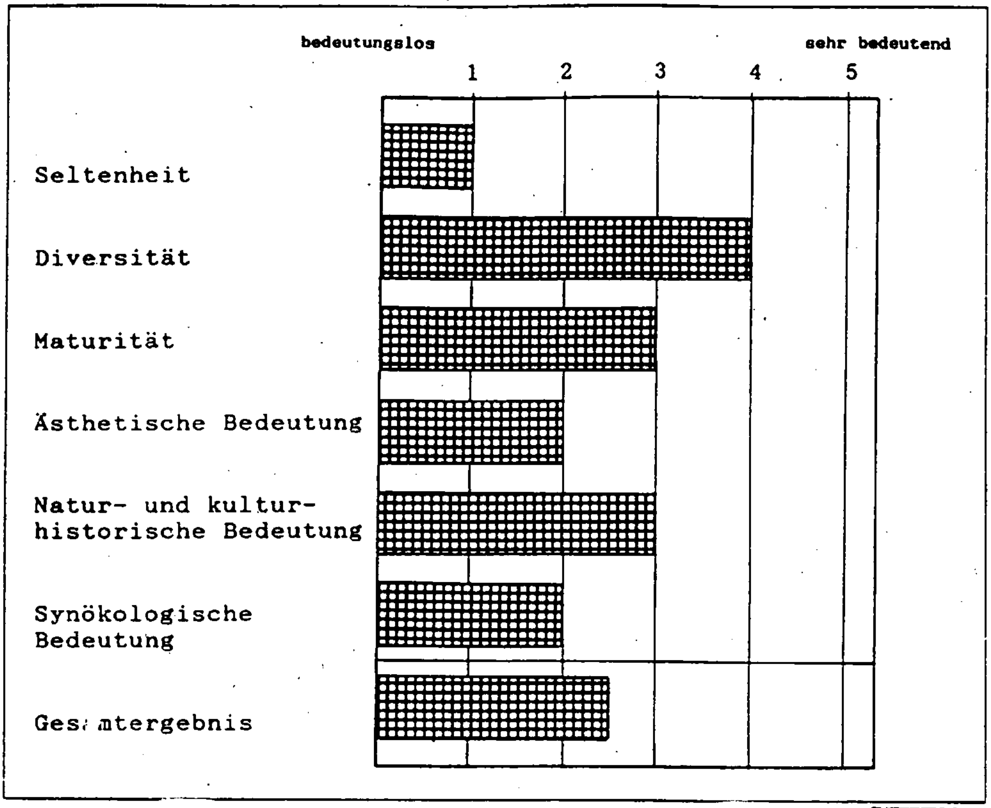


Figure 4 *The classification of a wet meadow under consideration of its protection value (ULLRICH, R. 1992, Fig.17, p.70)*

Furthermore, this submitted information can be processed into diagrams or graphs, like those being created by the author. These graphs which survey ecosystems were created for some parts of the karst regions located in the Mittelgebirges of southern Germany (Figure 5).

In addition, it is possible to create tabular summaries consisting of specific instructions that are only valid for certain regions. Table 2 shows an extract of the instructions for a planned nature reserve (HACK 1991). This table helps to estimate resulting costs and cultivation measures.

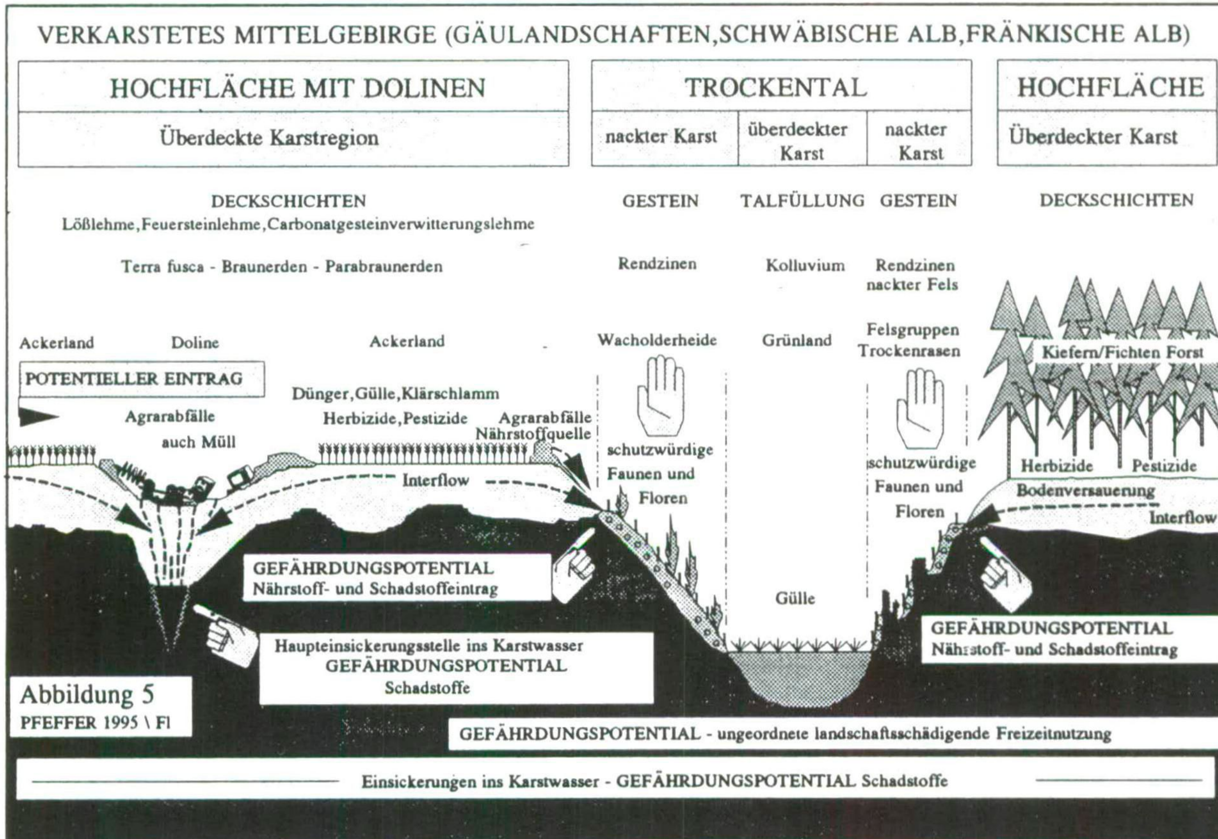


Figure 5 *The survey of an ecosystem showing ways of protection management*

Nr.	FLURSTÜCKNAME	BESCHREIBUNG / BEWERTUNG	PFLEGE / VORGESCHLAGENE MAßNAHMEN
1	Bauernofenbuckel 55 000 m^2	**Reine Wacholderheide, besonders hochwertige Flora** Wacholderheide von Gentiana verna-Brometum-Typ mit zahlreichen geschützten und seltenen Arten (u.a. Carlina acaulis, Daphne cneorum, Gentiana verna, Globularia punktata, Pulsatilla vulgaris). Wegen kleinsträumigen Wechsels von sehr flachgründigen, sandigen Rendzinen an vollsonnigen, trockenen Standorten und schattseitigen, frischeren Standorten, bzw. engen Dolomitsandgruben, bietet die Wacholderheide Bauenofen verschiedenste ökologische Nischen. Sie kann daher als ökologisches Kleinod bezeichnet werden.	Bewahrung des vielfältigen Charakters. Schaffung größerer schattenfreier Rasenflächen, bevorzugt im zentralen und südseitigen Teil. Stark verbuschte Bereiche auflichten, breitwüchsige Wacholder zurückstutzen, um wieder eine übersichtlichere Schafweide zu schaffen. <u>1. westlicher Teil</u> Erstpflege wurde durchgeführt. Dringend Nachpflege durchführen und die zahlreich aufkommenden Fichten- und Kiefernsämlinge "köpfen". <u>2. östlicher Teil</u> Wacholder vereinzeln; vor allem weitausladende Wacholder/-gruppen stark zurückstutzen. Fichten und Kiefern bis auf markante Einzelexemplare entfernen. Gebüsch in den Sandgruben schonen.
2	Spitzwald 35 000 m^2	**Wacholder-Buchenheide, hochwertige Flora** (u.a. Carlina acaulis, Daphne cneorum, Pulsatilla vulgaris). Kiefernsukzession auf sehr flachgründigen Rendzinen in Südexposition; wenig offene Rasenflächen bis hin zu lichtem Kiefernwald.	Schaffung eines baumfreien Halbtrockenrasen am Unterhang; hangaufwärts Übergang zu lichter "Wacholder-Kiefern-Heide"; NE-Ende: Freistellung der Weidbuchen mit Übergang zum Buchenmischwald. <u>1. Unterhang</u> Am NW-Ende wurden bereits Erstpflegemaßnahmen durchgeführt. Auf der gesamten Breite dringend Kiefernaufwuchs (1 bis 2m hoch) entfernen; zum NE-Ende hin Weidbuchen freistellen. <u>2. Mittelhang</u> Auf Gesamtfläche die schlechtwüchsigen Kiefern hangaufwärts zurückdrängen; als Übergang zum Buchenwald einen Saum aus lichtem Kiefernwald erhalten.
3	Alter Hau	**Stark mit Schlehen verbuschte Heide** Baumgruppe, Feldgehölz; Dolomitsandgruben.	Zwischen Weidebuche und Fichtengruppe Freiraum herstellen. Parkartiges Biotop anstreben. Verbund mit Spitzwald und Bauenofen. Im zentralen Teil das Schlehengebüsch entfernen, einzelne Fichten fällen.

Table 2 *The evaluation of several areas and suggestions for the protection management (extracted from table 7, HACK, T. 1991, p.76)*

7. Outlook

A new line of karst research in physical geography evolved by the application of these methodical techniques which were described by examples. In combination with the applied techniques of human geography, interest will be focused on this line. Due to the international cooperation with colleagues who are more interested in botanic and/or climatic ecology -like with the former department of Mr JAKUCS - new ways will be found to quantify the status quo of nature, as well as human impact in karst regions.

Furthermore, these new techniques also made a contribution to the successful international cooperation on a higher level due to the establishment of the "STUDY GROUP ON MAN'S IMPACT IN KARST" of the IGU and the emerged commission "ENVIRONMENTAL CHANGES AND CONSERVATION IN KARST AREAS" under the active chairman Ugo SAURO, Padova.

A new era of karst research in the context of research in karst ecosystems has begun throughout the world.

8. Acknowledgements

The author is grateful to Barbara Götz whose careful translations significantly improved this paper.

9. References

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